RESEARCH OBJECTIVES, OPPORTUNITIES AND FACILITIES FOR MICROGRAVITY SCIENCE

Presented by Robert J. Bayuzick  
Office of Space Science and Applications  
NASA Headquarters and Vanderbilt University

ABSTRACT

Microgravity Science in the U.S.A. involves research in fluids science, combustion science, materials science, biotechnology and fundamental physics. The purpose is to achieve a thorough understanding of the effects of gravitational body forces on physical phenomena relevant to those disciplines. This includes the study of phenomena which are usually overwhelmed by the presence of gravitational body forces and, therefore, chiefly manifested when gravitational forces are weak. In the pragmatic sense, the research involves gravity level as an experimental parameter.

Calendar year 1992 is a landmark year for research opportunities in low earth orbit for Microgravity Science. For the first time ever, three Spacelab flights will fly in a single year. IML-1 was launched on January 22; USML-1 was launched on June 25; and, in September, SL-J will be launched. A separate flight involving two cargo bay carriers, USMP-1, will be launched in October. From the beginning of 1993 up to and including the Space Station era (1997), nine flights involving either Spacelab or USMP carriers will be flown. This will be augmented by a number of middeck payloads and get away specials flying on various flights.

All of this activity sets the stage for experimentation on Space Station Freedom. Beginning in 1997, experiments in Microgravity Science will be conducted on Station. Facilities for doing experiments in protein crystal growth, solidification and biotechnology will all be available. These will be joined by middeck-class payloads and the microgravity glove box for conducting additional experiments. In 1998, a new generation protein crystal growth facility and a facility for conducting combustion research will arrive. A fluids science facility and additional capability for conducting research in solidification, as well as an ability to handle small payloads on a quick response basis, will be added in 1999. The year 2000 will see upgrades in the protein crystal growth and fluids science facilities. From the beginning of 1997 to the fall of 1999 (the “man-tended capability” era), there will be two or three utilization flights per year. Plans call for operations in Microgravity Science during utilization flights and between utilization flights. Experiments conducted during utilization flights will characteristically require crew interaction, short duration and less sensitivity to perturbations in the acceleration environment. Operations between utilization flights will involve experiments that can be controlled remotely and/or can be automated. Typically, the experiments will require long times and a pristine environment. Beyond the fall of 1999 (the “permanently-manned capability” era), some payloads will require crew interaction; others will be automated and will make use of telescience.
Microgravity Science and Applications Division
Research Objectives, Opportunities, and Facilities

Presented to:
Space Station Freedom Utilization Conference
August 3 - 6, 1992
Huntsville, Alabama

Robert J. Bayuzick
Develop a comprehensive research program in fluids science, combustion science, materials science, biotechnology, and fundamental physics for the purpose of attaining a structured understanding of gravity-dependent physical phenomena and those physical phenomena made obscure by the effects of gravity.

- Multiphase flow and heat transfer
- Suspension/colloid/granular media mechanics
- Solid-fluid interface dynamics
- Capillary phenomena
- Magneto/electrohydrodynamics
- Transport phenomena
Combustion Science Research Areas

- Ignition, smolder, solid materials
- Gaseous diffusion flames
- Gaseous premixed flames
- Heterogeneous (particles and droplets)
- Metals and combustion synthesis

Materials Science Research Areas

Electronic and Photonic Materials
Metals and Alloys
Glasses and Ceramics

or

Crystal Growth
Solidification Fundamentals
Thermophysical Properties
Biotechnology Research Areas

- Cell physiology
- Cell differentiation
- Protein crystal growth
- Biological separations

Fundamental Physics Research Areas

- Critical point phenomena
- Gravitational physics
FLIGHT OPPORTUNITIES -- THE PRESENT

- Four MSAD missions in CY92:

  **IML-1** – successful mission: January 22 - 30, 1992
  **USML-1** – successful mission: June 25 - July 9, 1992
  **Spacelab-J**
  **USMP-1**
### Fluids Experiment System
- A Study of Solution Crystal Growth in Low Gravity
- Casting and Solidification Technology

### Vapor Crystal Growth System
- Mercuric Iodide Crystal Growth
- Protein Crystal Growth
- Organic Crystal Growth Facility
- Cryostat
  - Protein Crystal Growth in Cryostat
  - B-galactosidase/Inhibitor-Single Crystal Growth
  - Crystal Growth of Electrogenic Membrane Protein
    - Bacteriorhodopsin

### Critical Point Facility
- Critical Fluid Thermal Equilibrium
- Heat and Mass Transport at the Critical Point
- Light Scattering and Interferometry Experiments

### Space Acceleration Measurement System

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<th>Acronym</th>
<th>Principal Investigator</th>
<th>Country of Origin</th>
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## Microgravity Science and Applications Division Baseline Plan: 1994 - 2004

### FUNDAMENTAL SCIENCE

- Condensed Matter Physics
  - Lambdoid Point Experiment
  - Critical Fluid Light Scattering Experiment
  - Critical Fluid Geometric Measurement Experiment
  - Low Temperature Research Facility
  - Satellite Text of Equivalence Principle

- Fluids & Transport Phenomena
  - Surface Tension Driven Convection Experiment
  - Drop Physics Module
  - Critical Point Facility (F)
  - Bubble, Drop, and Particle Unit (F)
  - Geophysical Fluid Flow Cell
  - Mechanics of Granular Materials
  - Advanced Fluids Multipliers
  - Advanced Fluids Module
  - Fluid Physics/Dynamics Facility
  - Modular Controllability Processing Facility

- Combustion Science
  - Solid Surface Combustion Experiment
  - Advanced Combustion Modules
  - Modeling Combustion Facility

### MATERIALS SCIENCE

- Metals and Alloys
  - Isothermal Dendrite Growth Experiment
  - TEMPS (F)
  - Large Isothermal Furnace (F)
  - Space Station Furnace Facility

- Glasses and Ceramics
  - Drop Physics Module
  - Modular Controllability Processing Facility

- Electronic & Photonic Materials
  - Crystal Growth Furnace
  - Mephistro (F)
  - Advanced Protein Crystal Growth
  - Advanced Protein Crystal Growth Facility

### BIOTECHNOLOGY

- Call Science
  - Protein Crystal Growth
  - Crystallographic (F)

### SO & DA

- Space Acceleration Measurement System
- Glovebox Experiment Module

### R & A

- Drop Tubs/Towers
  - Parabolic Flights
  - Sounding Rockets

### ATD

- Advanced Furnace Technology
- Non-Contact Temperature Measurement
- Laser Light Scattering Experiment
- Interface Measurements

### Microgravity Science and Applications Division Planning Manifest

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### Microgravity Science and Applications Division

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Microgravity Science and Applications Division

Planned Research Announcements

Calendar Year: 91 92 93 94 95 96 97

Combustion Science ▼ ▼ ▼ ▼ ▼ ▼ ▼
Biotechnology ▼ ▼ ▼ ▼ ▼ ▼ ▼
Fluids and Transport ▼ ▼ ▼ ▼ ▼ ▼ ▼
Materials Science ▼ ▼ ▼ ▼ ▼ ▼ ▼
Fundamental Science ▼ ▼ ▼ ▼ ▼ ▼ ▼

Ground-Based Research ▼ ▼ ▼ ▼ ▼ ▼ ▼ ▼
Microgravity Science and Applications
Division FY92 Budget by Program

- Science: $1,995K
- Biotechnology: $2,183K
- Protein Crystal Growth (PCG): $4,761K
- Containerless: $14,908K
- Advanced Technology Development (ATD): $1,870K
- HQ & Center Support: $26,596K
- Research and Analysis (R & A): $16,600K
- Solidification: $21,025K
- Fluids: $9,658K
- Combustion: $6,810K
- Fundamental Science: $9,147K

Total: $120,800K

Microgravity Science and Applications Space Station Facilities
Integrated Launch Schedule

Overall Flight Sequence

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Utilization Flight Increment

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MSAD Space Station Payload Traffic Model (April 1992)

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* SAMS SSF is Station-unique hardware, not transition hardware
- Evaluate the effects of gravity on the growth of protein crystals
- Study physics/dynamics of macromolecular crystal growth
- Support biotechnology research by growing high quality macromolecular protein crystals which can be used for x-ray crystallography
Advanced Protein Crystal Growth (APCG)
Payload Description (1997 - 1998)

- Power 0.5 kW nominal/1 kW peak
- Mass 300 kg
- Volume 1 rack

TRANSITION HARDWARE
2 Thermal Enclosure System (TES) units with crystal growth apparatus
SSFP provides adapter hardware, integration

- APCG plans to accommodate second generation crystal growth hardware in TES units
  - Vapor Diffusion Apparatus
  - Thermally-controlled batch process
  - Liquid-liquid diffusion
  - Dynamically-controlled systems
- Automated experiment initiation and deactivation


- Power 2.1 kW nominal/2.4 kW peak
- Mass 616 kg
- Volume 1 rack

Space Station-unique hardware
Advanced thermal enclosures
Enhanced diagnostic systems with imaging capability

- Third generation protein crystal growth hardware
  - May accommodate a larger number of experiments than APCG by using advanced thermal enclosures
  - Can accommodate current TES, new thermal enclosures, or PI-supplied thermal enclosures for long-duration crystal growth, and enhanced diagnostics
  - Automated experiment initiation and deactivation
- Gain understanding of the mechanisms which correlate directional solidification parameters and materials properties for various technologically important materials

- Explore potential for utilization of low gravity environment to develop unique materials or materials structures which have unique, crafted properties

- Measure thermophysical properties of materials
Space Station Furnace Facility/Crystal Growth
Furnace Payload Description
(1997 - 1998)

- Power 2.0 kW nominal/4.0 kW peak
- Mass 1050 kg
- Volume 2 racks
  - 1 Rack - Core  Space Station-unique controls, power conditioning and diagnostics
  - 1 Rack  CGF furnace
    - Pressure vessel with flexible glovebox
    - Reconfigurable furnace module
    - Furnace translation mechanism
    - Automated sample exchange mechanism (up to six samples)

- Gradient zone thickness can be optimized before launch, and a heat extraction plate can be included to obtain steeper gradients
- Interface demarcation will be available by mechanical and current pulsing

Space Station Furnace Facility (SSFF)

- Power 6.5 kW nominal/9.0 kW peak
- Mass 1,350 kg
- Volume 3 racks
  - 1 Rack - Core  Space Station-unique controls, power conditioning and diagnostics
  - 1 Rack  Furnace Module 1
  - 1 Rack  Furnace Module 2

- Furnace Modules -- to be determined from NASA Research Announcement/Announcement for Opportunity (NRA/AO) selection -- first PI selections in August 1992
- Modules being considered
  - Upgraded programmable Multi-Zone Furnace (used for planning purposes)
  - Transparent Furnace
  - Bridgman with Quench
  - Float-Zone Crystal Growth Furnace
• Provide better understanding of fundamental theories of combustion processes and phenomena, such as:
  - Premixed gaseous fuel combustion
  - Laminar and turbulent diffusion flames
  - Flame spreading and smoldering with solid fuels
  - Flame spreading over liquid pools
  - Effectiveness of fire extinguishing techniques
  - Droplet, particle, and spray combustion
  - Metals combustion

• Provide scientific and engineering data for a variety of combustion related applications, such as spacecraft fire safety
Advanced Combustion Middeck Payload

- Power: 120 W
- Mass: 400 kg
- Volume: 4 middeck lockers

- A CoDR was held in December 1991
- Will have the capability to do multiple experiment samples intensified video for low luminosity
- Studying the capability for chamber atmosphere clean-up

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Modular Combustion Facility (MCF)
Payload Description (1998 - 2000)

- Power: 1.5 kW nominal/2.3 kW peak
- Mass: 1,400 kg
- Volume: 2 racks

**TRANSITION HARDWARE**

1 Rack - Core
Shares a common core with the fluids module
1 Rack - Module 1 - Combustion experiment rack

- The combustion experiment rack will house a generic combustion chamber with investigation-specific equipment
  - Nozzles for burning of gases
  - Sample holders for solid fuels experiment
- The combustion chamber will have ports to accommodate different modular diagnostics systems:
  - CCD video system
  - Infrared imager
  - Schlieren imaging system
  - Temperature measuring probes
  - Gas sampling probes
Modular Combustion Facility (MCF)
Payload Description (2001+)

- Power: 5 kW nominal/7.1 kW peak
- Mass: 1,400 kg
- Volume: 2 racks

STATION-UNIQUE HARDWARE
1 Rack - Core
Core 2 shared with fluid modules

1 Rack
Module 2 - combustion experiment rack

- Module 2 to be determined from NRA/AO selection
- Two candidate experiment racks under study
  - Quiescent Combustion Chamber
  - Low-Speed Combustion Tunnel

Fluid Physics and Dynamics
Science Utilization

- Provide advances in theories of fluid physics
- Provide improvements in thermophysical property measurement
- Provide scientific and engineering data related to fluids-related applications and systems
- Experiments may cover a broad area of interest:
  - Isothermal-isosolutal capillary phenomena
  - Capillary phenomena with thermal/solutal gradients
  - Thermal solutal convection and diffusive flows
  - First order phase transitions in a static fluid
  - Multi-phase flow
Fluids Program Evolution

**Fluids Experiment System (1985, 1992)**
- Spacelab, multi-user

- Surface Tension
- Driven Convection Experiment
- Spacelab, PI-specific

- Pool Boiling Experiment
- Get away special payload, PI-specific

**AEM (1999)**
- Advanced Fluids Module for SSF
- Multi-user module added to Fluids/Combustion core facility

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**Fluid Physics Dynamics Facility (FPDF) Payload Description (1999+)**

- **Power**
  - Fluids Module 1: 2.0 kW nominal/3.0 kW peak
  - Fluids Module 2: 5.9 kW nominal/9.5 kW peak

- **Mass**
  - 700 kg

- **Volume**
  - 1 rack
  - Core shared with MCF


- **Modules 1 and 2 -- to be determined by AO/NRA selection**
- **Two candidate experiment racks under study**
  - Support dynamic fluid experiments in a multi-phase apparatus
  - Vibration isolation containment enclosure for sealed-cell experiments

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- Accommodate experiments requiring the positioning and manipulation of materials without physical contact with container walls

- Conduct research on properties and phenomena that on Earth are seriously affected by container contamination, container-generated nucleations, and gravity effects
Modular Containerless Processing Facility (MCPF) Payload Description (under review)

- Power: 2.5 kW nominal/3.0 kW peak
- Mass: 700 kg
- Volume: 1 rack

Sample positioning devices
Diagnostics and control

- Levitation modules to position the sample may be electrostatic, electromagnetic, acoustic fields, or a hybrid combination

- Gain understanding in vast area of physical sciences ranging from the behavior of liquid drops in space, the measurement of thermophysical properties of materials, and the characterization of metals, glasses, and ceramics heated to temperatures up to 2700°C

Biotechnology
Science Utilization

- Study cell function and differentiation in a low mechanical stress environment
- Culture end-differentiated tissue models for studies of genetic regulations
Biotechnology Program Evolution

**IES (1984, 1988)**  
Isoelectric Focusing  
Middeck, PI-specific

Phase Partitioning Experiment  
Middeck, PI-specific

**BTF (1997)**  
Biotechnology Facility for SSF  
Host Facility for future investigations in  
Cell culturing  
Cell separations  
Future areas of Biotechnology

Bioreactor (DSO in 1991  
future flights TBD)  
Rotating wall cell culturing system  
Middeck, multi-user  
Awaiting results of 1991  
Biotechnology NRA to determine future flight development

**BTF (1997)**  
Biotechnology Facility Payload Description (1997+)

- **Power**: TBD kW nominal and peak
- **Mass**: 700 kg
- **Data**: TBD Kbits/sec
- **Volume**: 1 rack

- The BTF will accommodate a series of PI-developed, self-contained biotechnology experiments. BTF "services" will include power conditioning and distribution, video and data processing, and basic gases and fluids.

- Concept may serve as the basis for a Small and Rapid-Response (SRR) Payload (1999)
"Middeck Class"
Payloads (1997+)

- Power: TBD kW nominal and peak
- Mass: TBD
- Data: TBD Kbits/sec
- Volume: 2 racks

**TRANSITION HARDWARE**
Middeck-class experiments
SSFP provides adapter hardware, integration

- The SSFP-provided Middeck Class Payload Adapter (MDC) will host a series of small to moderate-scale microgravity experiments by providing an interface that emulates the Shuttle middeck Experiments in Fluids and Transport Phenomena, Combustion, Materials Science
- MDC Accommodations will be similar to those provided by the SSFP interface hardware used for the APCG Transition Payload

**SSFP-Provided Microgravity Glovebox**
(1997+)

- Power: TBD kW nominal and peak
- Mass: 700 kg
- Data: TBD Kbits/sec
- Volume: 1 rack

- The SSFP-Provided Materials Science Glovebox (MSG) provides an enclosed work space isolated from the SSF ambient environment for handling microgravity science samples and hardware
- The MSG will accommodate a series of small-scale microgravity science experiments and technology demonstrations
- MSG services will include video and film cameras with appropriate lighting, temperature control and heat rejection in the work volume, power outlets for use by experiments and apparatus for recovering fluid spills
Utilization Flights

- All Microgravity Science and Applications Division (MSAD) payloads plan to operate during utilization flights.
- Some operations will be very similar to Spacelab:
  - High-speed film cameras for data storage
  - Discipline-emphasis crew skills
- Operations unlike Spacelab:
  - On-orbit rack changeout
  - Logistics/resupply (gases), sample harvesting, and changeout for return
  - Experiment set up for ground-tended runs

Unmanned Operations

- All MSAD payloads except combustion plan to operate during ground-tended operations.
- Payloads will require uplink communications:
  - For initiating run sequences
  - Power on/off
  - Restart experiment run
- Payloads will require downlink:
  - Monitoring experiment runs
  - Health and safety
  - Quick-look analysis
Operational Intent of MSAD-MTC

- Two to three 16-day utilization flights each year
- **Operation of facilities during utilization flights**
  - Experiments requiring crew interaction
  - Shorter duration experiments
  - Experiments that are less sensitive to "noisy" acceleration environment
- **Operations between utilization flights (ground-tended periods)**
  - Experiments that can be controlled remotely and/or automated
  - Longer duration experiments
  - Experiments requiring a pristine environment
- **Operations during assembly flights**
  - Conducted on a non-interference basis
  - May be limited to changing out samples and setting up experiments to be initiated later

Operational Intent of MSAD-PMC

- Payloads requiring crew interactions
- Automated payloads utilizing telescience methods
- Crew time is a limited resource
Summary

- Science return from MSAD payloads will begin in 1997 after launch of the U.S. Laboratory and will continue through 2000+
  - MSAD plans to conduct a broad range of experiments during the unmanned periods prior to PMC, during utilization flights, and PMC and beyond on SSF

- Science operations conducted during the utilization flights will be similar to Spacelab flights except for the added tasks of collecting and securing of samples, experiment setup for unmanned runs, and rack/module equipment changeout

- Unmanned operations will require automation of payloads and telescience but minimal two-way communications between MSAD payloads and the ground is intended

Microgravity Science and Applications Program Summary

- Active, growing, diverse program
- Areas of research
  - Biotechnology
  - Combustion
  - Fluids Science
  - Fundamental Physics
  - Materials Science
- Continuing to find new experimental possibilities
  - Encouraging science community to participate
  - Soliciting science proposals through NRA’s
  - Facilitating their development
- Collaborating with the international science community
  - Sharing use of facilities
- Looking forward to an exciting decade in microgravity research
• Community involvement in the program
  - Four DWG's plus Microgravity Subcommittee to Space Science and Applications Advisory Committee (SSAAC)

• National Academy of Sciences
  - Microgravity Science Committee of the Space Studies Board
    -- Established in 1988
    -- First meeting in 1990
  - Development of long-term strategy for microgravity sciences

• Integrate microgravity initiatives into OSSA program
  - SSAAC review and advice
  - OSSA Strategic Plan
### SSB Committee on Microgravity Research
#### Membership List

**Chairperson**

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<tr>
<th>Name</th>
<th>Position</th>
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<td>William A. Sirignano</td>
<td>Chair</td>
<td>Department of Engineering, University of California at Irvine</td>
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<tr>
<td>Richard C. Hart</td>
<td>Space Studies Board</td>
<td>National Academy of Science</td>
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<tr>
<td>Robert A. Brown</td>
<td>Head of Chemical Engineering</td>
<td>Mass Institute of Technology</td>
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<td>Martin E. Glicksman</td>
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<td>Rensselaer Polytechnic University</td>
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<td>Franklin D. Lemkey</td>
<td>Materials Technology Laboratory</td>
<td>United Technologies Research Center</td>
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<td>Case Western Reserve University [Fluid Flow and Transfer]</td>
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<td>University of Michigan</td>
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<td>Morton B. Panish</td>
<td>Distinguished Member of the Technical Staff</td>
<td>AT&amp;T Bell Laboratories</td>
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<td>John D. Reppy</td>
<td>Laboratory of Atomic and Solid State Physics</td>
<td>Cornell University [Physics]</td>
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### Membership of Microgravity Science and Applications Subcommittee (MSAS)

**Chair:** Dudley Saville  
Chemical Engineering Department  
Princeton University

**Exec. Secretary:** Roger Crouch  
NASA Headquarters  
MSAD Chief Scientist

**MEMBERS**

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<td>Oliver Willen</td>
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### Members and Affiliations (SSSAAS)

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<td>Dr. Robert J. Bayuzick</td>
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<td>Marshall Space Flight Center</td>
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<tr>
<td>Dr. Benton C. Clark</td>
<td>Martin Marietta Astronautics Group</td>
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<td>Dr. Earl L. Cook</td>
<td>3M Corporation</td>
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<tr>
<td>Dr. Alan C. Eckbreth</td>
<td>United Technologies Research Center</td>
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<tr>
<td>Dr. John E. Estes</td>
<td>University of California, Santa Barbara</td>
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<tr>
<td>Dr. Jeffrey A. Hoffman</td>
<td>Johnson Space Center</td>
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<td>Dr. Shannon W. Lucid</td>
<td>Johnson Space Center</td>
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<tr>
<td>Dr. Herman Merte, Jr.</td>
<td>University of Michigan</td>
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<tr>
<td>Dr. Cary Mitchell</td>
<td>Purdue University</td>
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<tr>
<td>Dr. Robert W. Phillips</td>
<td>NASA Headquarters (Visiting Scientist)</td>
</tr>
<tr>
<td>Dr. Sam L. Pool</td>
<td>Johnson Space Center</td>
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<tr>
<td>Dr. David Robertson</td>
<td>Vanderbilt University</td>
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<tr>
<td>Dr. Marc E. Tischler</td>
<td>University of Arizona</td>
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</tbody>
</table>

### Discipline Working Groups

- **Biotechnology**
  - Chair: Dr. Gary Gilliland (NIST)
  - Vice-Chair: Dan Carter (MSFC)

- **Combustion**
  - Chair: Dr. Gerard Faeth (University of Michigan)
  - Vice-Chair: Kurt Sacksteder (LeRC)

- **Fluids and Transport**
  - Chair: Stephen H. Davis (Northwestern University)
  - Vice-Chair: Bob Thomson (LeRC)

- **Materials Science**
  - Chair: John Perepecko (University of Wisconsin)
  - Vice-Chair: Frank Szofran (MSFC)
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NASA Marshall Space Flight Center

Prof. Tim Anderson
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Dr. Richard Hopkins
Science and Technology Center
Westinghouse Electric Corporation

Dr. Reid Cooper (ad hoc assignment)
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Dr. Robert Schaefer
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National Institute of Standards and Technology

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University of Wisconsin at Madison

Dr. Rohit Trivedi
Ames Laboratory
Iowa State University

Prof. Dennis Readey
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Colorado School of Mines

Prof. Peter Voorhees
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Division of Materials Research
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University of Oregon

Prof. Paul Nietzel
School of Mechanical Engineering
Georgia Institute of Technology

Dr. John Huang
Exxon Research and Engineering Company

Prof. Harry Swinney
Dept. of Physics
University of Texas at Austin

Prof. Richard Lahey
Dept. of Nuclear Engineering and Engineering Physics
Rensselaer Polytechnic Institute

Dr. Michael Moldover
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National Institute of Standards and Technology

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Mississippi State University

Prof. Robert Santoro
Mechanical Engineering Dept.
Pennsylvania State University

Dr. Raymond Friedman
Factory Mutual Research

Prof. Mitchell Smooke
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Prof. Jack Howard
Dept. of Chemical Engineering
Massachusetts Institute of Technology

Prof. Forman Williams
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Biotechnology
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Prof. Lola Reid
Dept. of Molecular Pharmacology
Albert Einstein College of Medicine

Prof. Forman Williams

Membership of Discipline Working Groups (DWG's)

**DWG**

= 8 - 12 members

<table>
<thead>
<tr>
<th>Role</th>
<th>Description</th>
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<tbody>
<tr>
<td>Chair</td>
<td>Unaffiliated (desired)</td>
</tr>
<tr>
<td>Ex Officio Member</td>
<td>Discipline Program Scientist</td>
</tr>
<tr>
<td>Vice-Chairperson</td>
<td>Center Scientist</td>
</tr>
<tr>
<td>4 Members</td>
<td>Principal Investigator(s) (2 maximum)</td>
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<tr>
<td>Member</td>
<td>Industry</td>
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<tr>
<td></td>
<td>Academia</td>
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<td></td>
<td>Other Government</td>
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